INVESTIGATION OF ELECTROWEAK INTERACTION THROUGH MEDIATOR

Mohammed Sultan

The 5th Egyptian School on High Energy Physics

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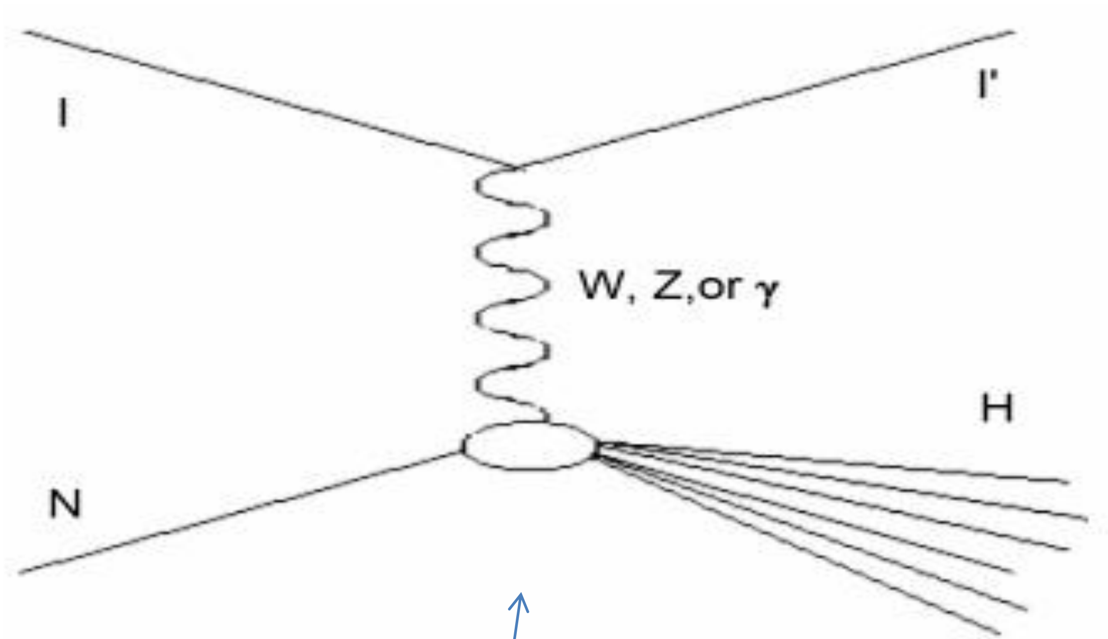
What I did?

- At high energy, I studied the interaction of weak particle as neutrino and the interaction of electroweak particle as muon.

- By comparing the results of these interactions we can look to the features of electroweak force.

Feynman diagram

- The last interaction can be described by Feynman diagram of two vertices.



Scattered lepton

Leptonic Current

Hadronic Current

Excited Proton

Decays by strong force to many hadrons in the final state.

Leptonic current # first vertex

- The leptonic current is given by:-

$$J^{\nu} = (g/2)\psi'(\nu')\underbrace{\gamma_{\mu}(1-\gamma_5)}_{\text{Weak vertex vector}}\psi(\nu) \qquad \textbf{(1)}$$

Wave function for scattered neutrino

Wave function for Incident neutrino

Weak vertex vector

γ_5 is a 4×4 matrix that defined in terms of the Dirac matrices as $\gamma_5 = i\gamma^0\gamma^1\gamma^2\gamma^3$

Wave function for incident ν ## Dirac Equation

- We deal with particles of spin ½ (Leptons) at high energies ($\lambda \sim 10^{-15}$m ~ hadron radii) .

- Relativistic Quantum Theory is described like these particles by Dirac equation: (Where: ħ = c = 1)

$$i\partial\psi / \partial t = (-i\alpha \cdot \nabla + \beta m)\psi$$

- Then the solution gives us a plane wave for the incident neutrino as:

$$\boxed{\psi(r) = u(p)e^{-ik.r}} \qquad \textbf{(2)}$$

❑The wave function for the scattered neutrino is determined by using perturbation technique as:

$$\psi'(k',r) = \left\{ \psi(k',r) + (2\pi)^{3/2} f \frac{\exp(ik'r)}{r} \right\} \qquad \textbf{(3)}$$

scattering amplitude

$$f = \sum f_1 + f_2 + ..$$

The sum runs over the possible orders of perturbation.

Wave function for scattered ν # Perturbation Theory#

$$f = V_{fi} + \int d^3 p_n \frac{V_{fn} V_{ni}}{E - E_n^0 + i\varepsilon} + \int\int d^3 p_{n'} d^3 p_n \frac{V_{fn'} V_{n'n} V_{ni}}{(E - E_{n'}^0 + i\varepsilon)(E - E_n^0 + i\varepsilon)}$$

$$+ ....$$

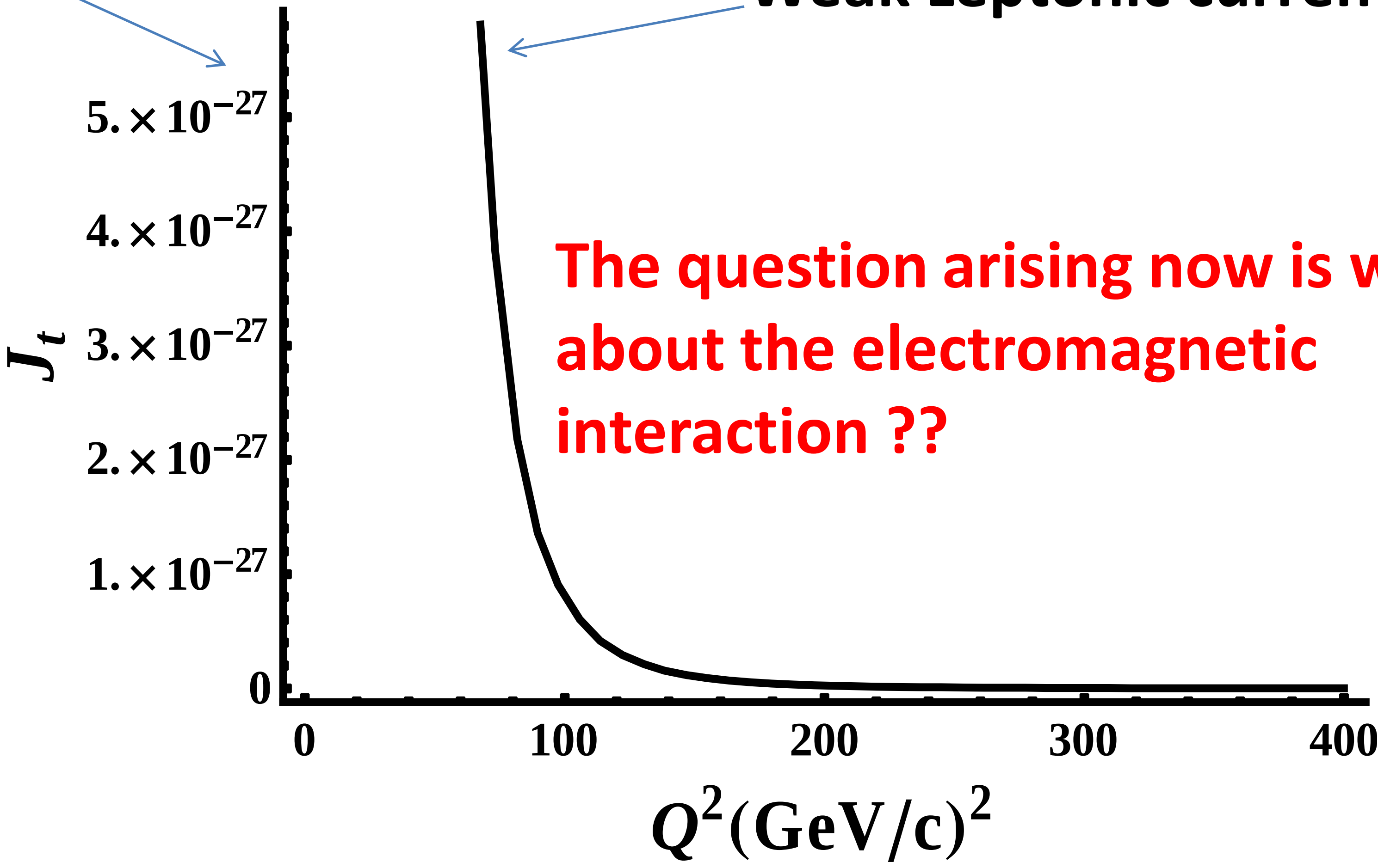
❑Since the scattering is due to weak field, then it is sufficient to consider only one term in previous series:

The first term is → $V_{fi} =< f \,|V(\vec{r})|\, i >$

Where the weak potential has the form: $V(\vec{r}) = V_0 \exp(-M_z r)$

Leptonic current produced by neutrino as function of Q^2

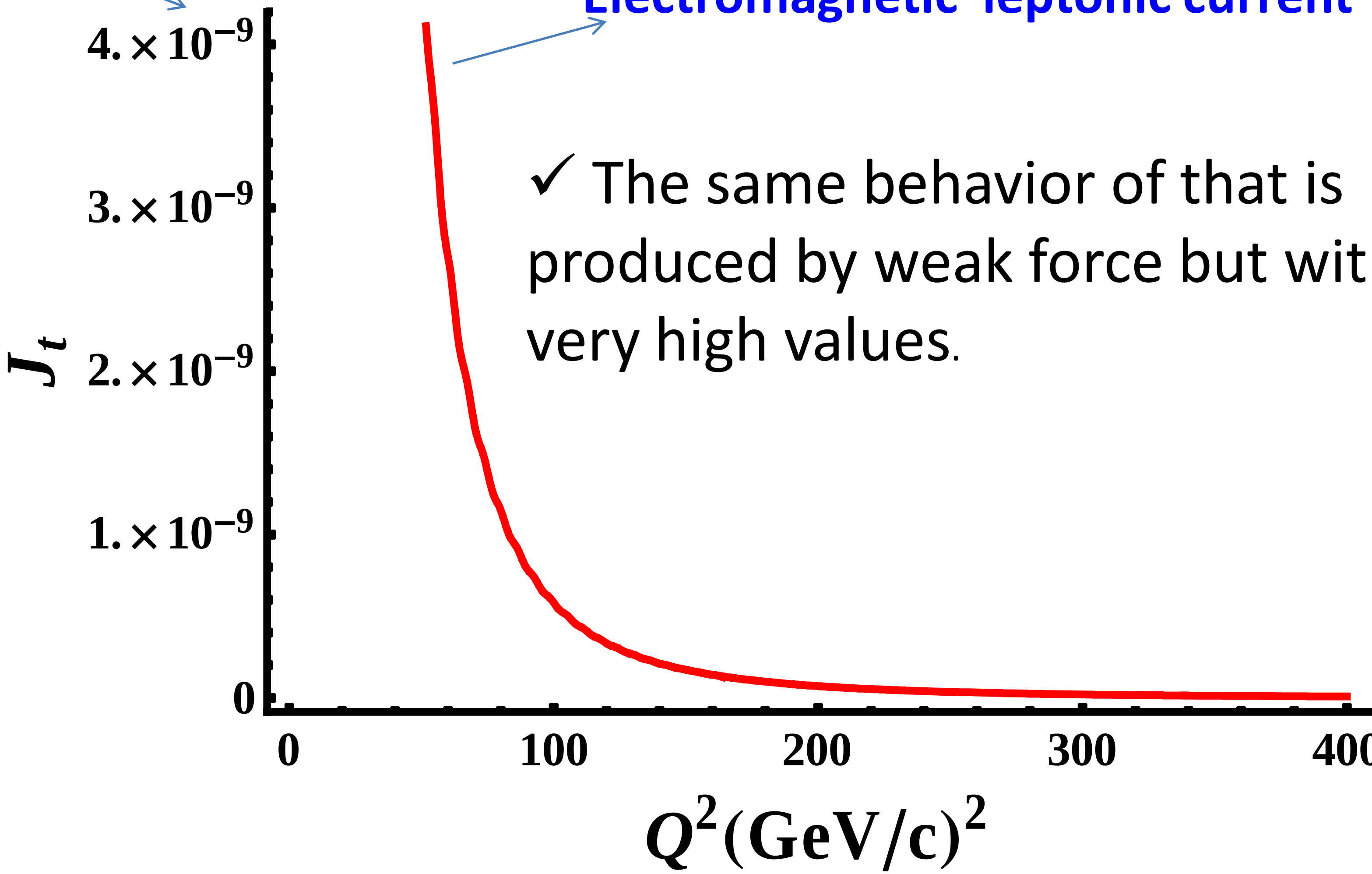
In order of



The question arising now is what about the electromagnetic interaction ??

Leptonic current produced by muon as function of Q^2

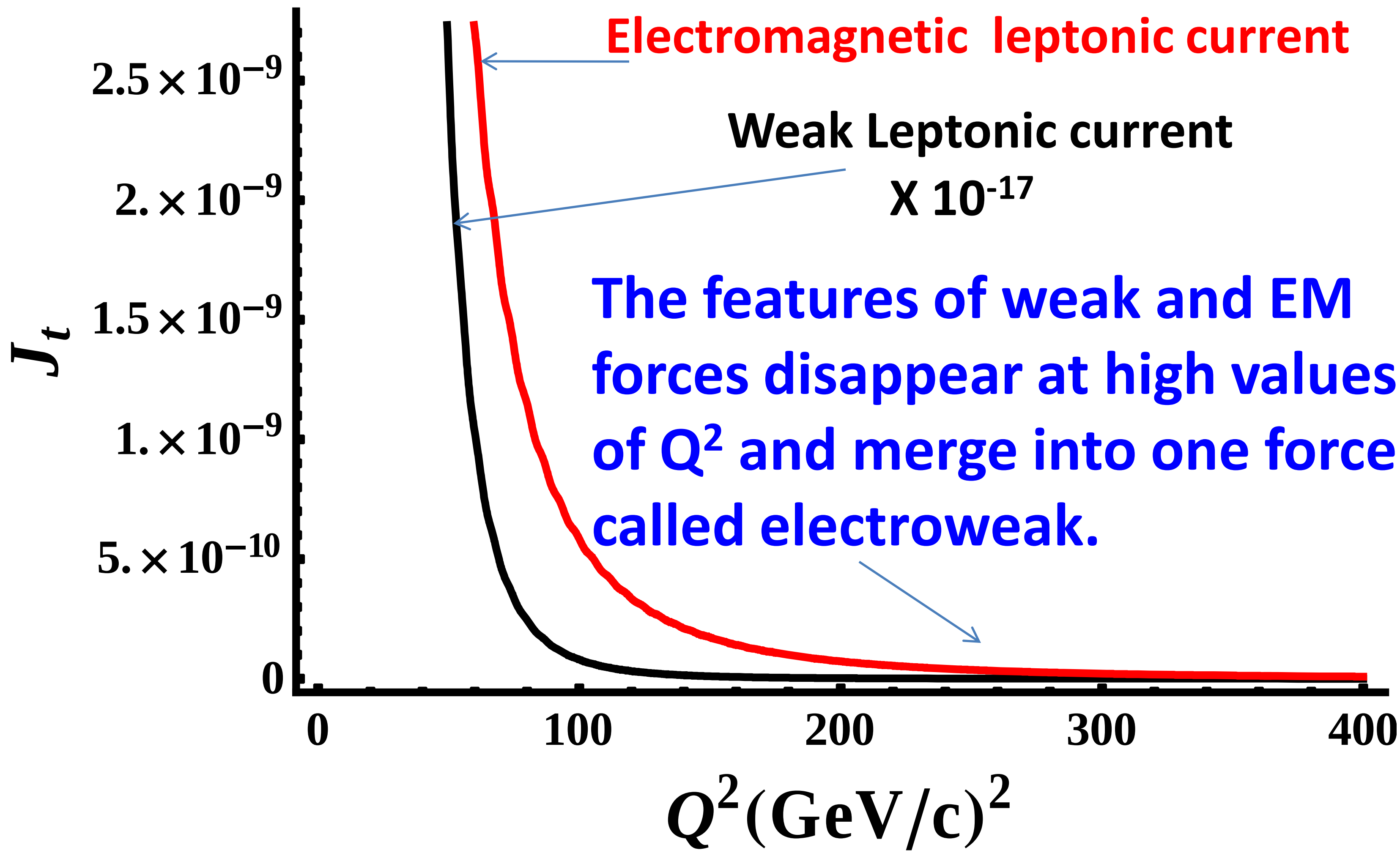
In order of



Electromagnetic leptonic current

✓ The same behavior of that is produced by weak force but with very high values.

Electroweak Leptonic current



Hadronic (or quark) current # # Second vertex

In general, quark current is defined as function of x(Bjorken parameter) and q^2 (the square transfer momentum) by:

$$J_q(x,q^2) = \sum \bar{u}(x,q'^2)\gamma_\mu \frac{1}{2}(1-\gamma_5)u(x,q'^2)$$

For all valence quarks

Vertex vector

Quark conjugate function

Quark wave function

❖ **It is interested to find the weak quark functions and the EM quark functions. Is there different ??**

Quark wave functions or PDFs

❑ The Standard Model suggests that :

➢ **The EM quark wave functions are given as:**

$$F_2^{\mu p} = \frac{4}{9}u(x) + \frac{1}{9}d(x) \qquad F_2^{\mu n} = \frac{4}{9}d(x) + \frac{1}{9}u(x)$$

➢ **The weak quark wave functions are given as:**

$$F_2^{\nu p} = 2x[d(x) + \bar{u}(x)] \qquad xF_3^{\nu p} = 2x[\bar{u}(x) - d(x)]$$

$$F_2^{\nu n} = 2x[\bar{d}(x) + u(x)] \qquad xF_3^{\nu n} = 2x[\bar{d}(x) - u(x)]$$

Structure functions

- All the needed data for muon and neutrino are collected at the same energy.

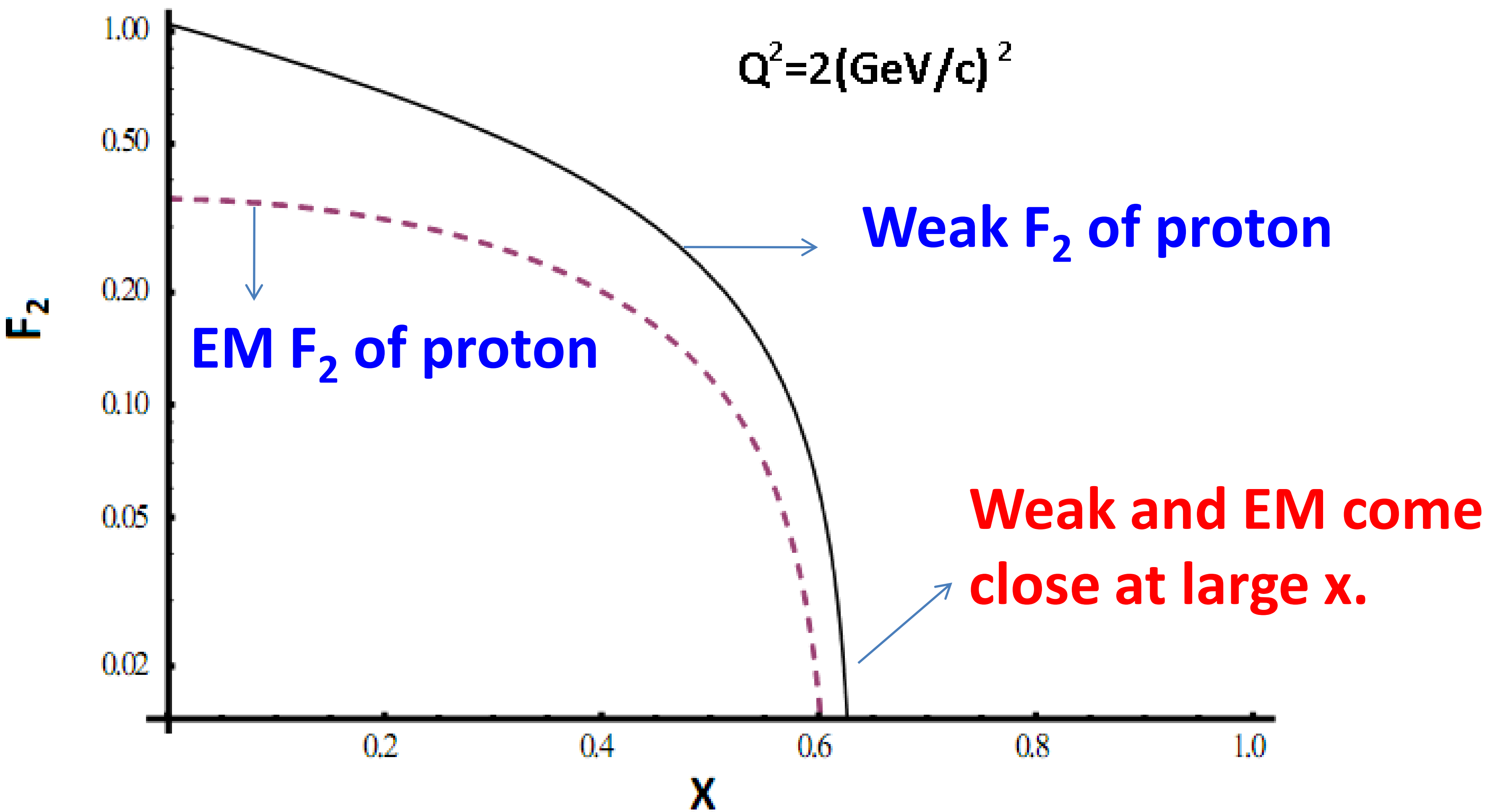
- I fitted the data to get a unique parametric form that can describe all data.

$$\boxed{F_{2,3}(x,Q^2) = A[x]e^{-B[x]Q^2}}$$

$$A[x] = a_0 + a_1 x + a_2 x^2$$

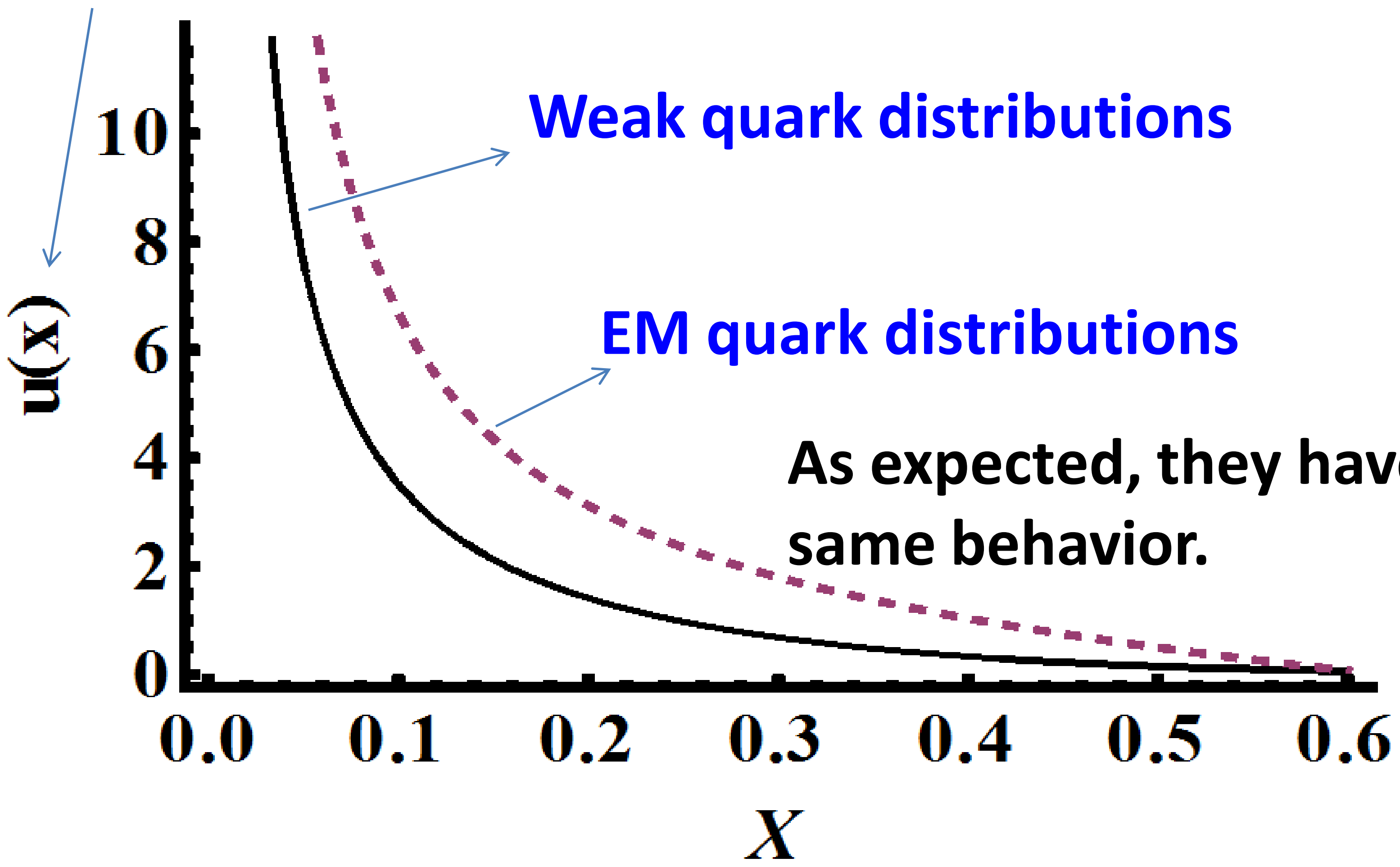
$$B[x] = b_0 + b_1 x + b_2 x^2$$

Results


Q^2=2(GeV/c)^2
Weak F_2 of proton
EM F_2 of proton
Weak and EM come close at large x.
F_2
1.00
0.50
0.20
0.10
0.05
0.02
0.2
0.4
0.6
0.8
1.0
X

Results

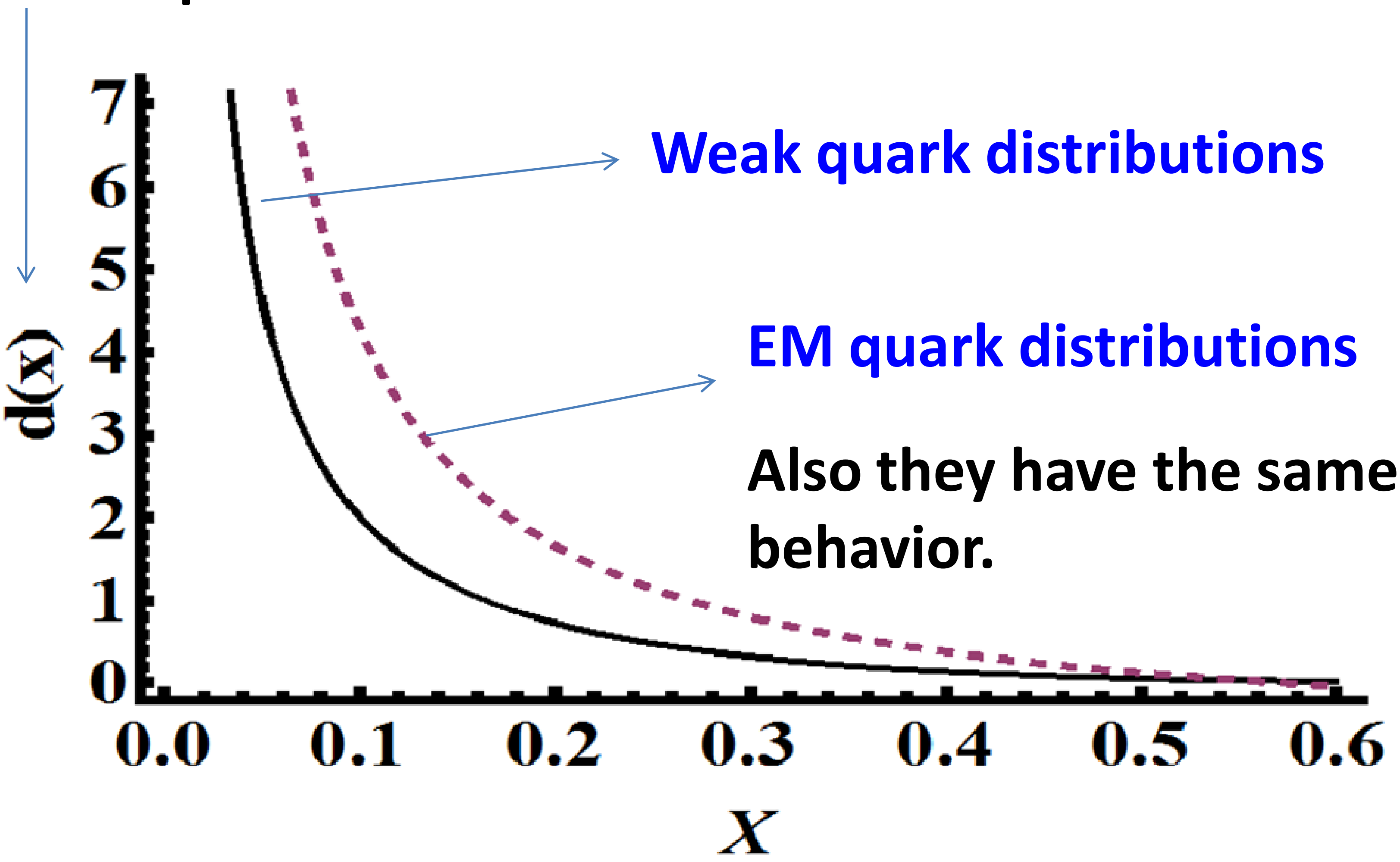
Up quark wave functions



As expected, they have the same behavior.

Results

Down quark wave function



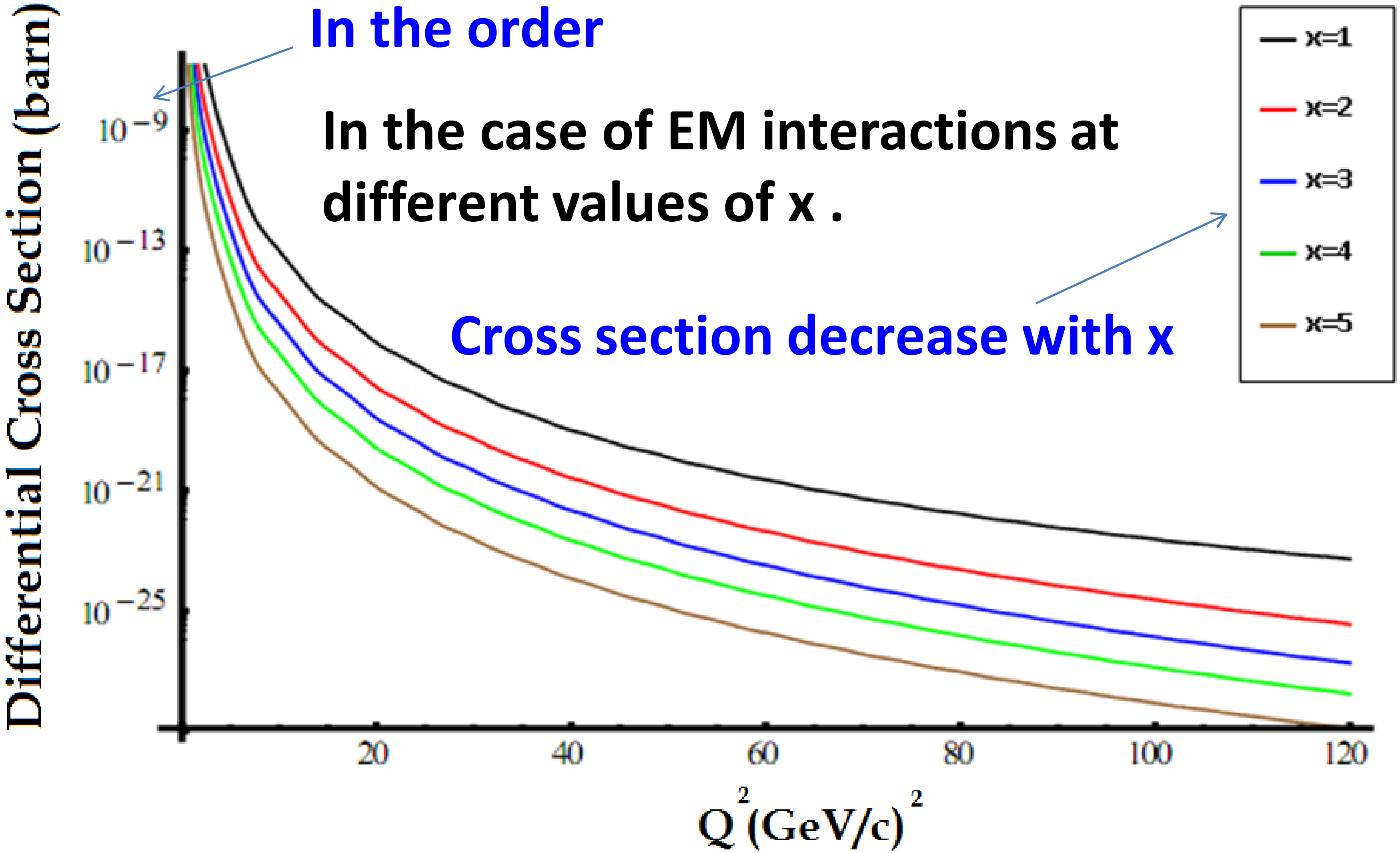
Also they have the same behavior.

Results

In the order

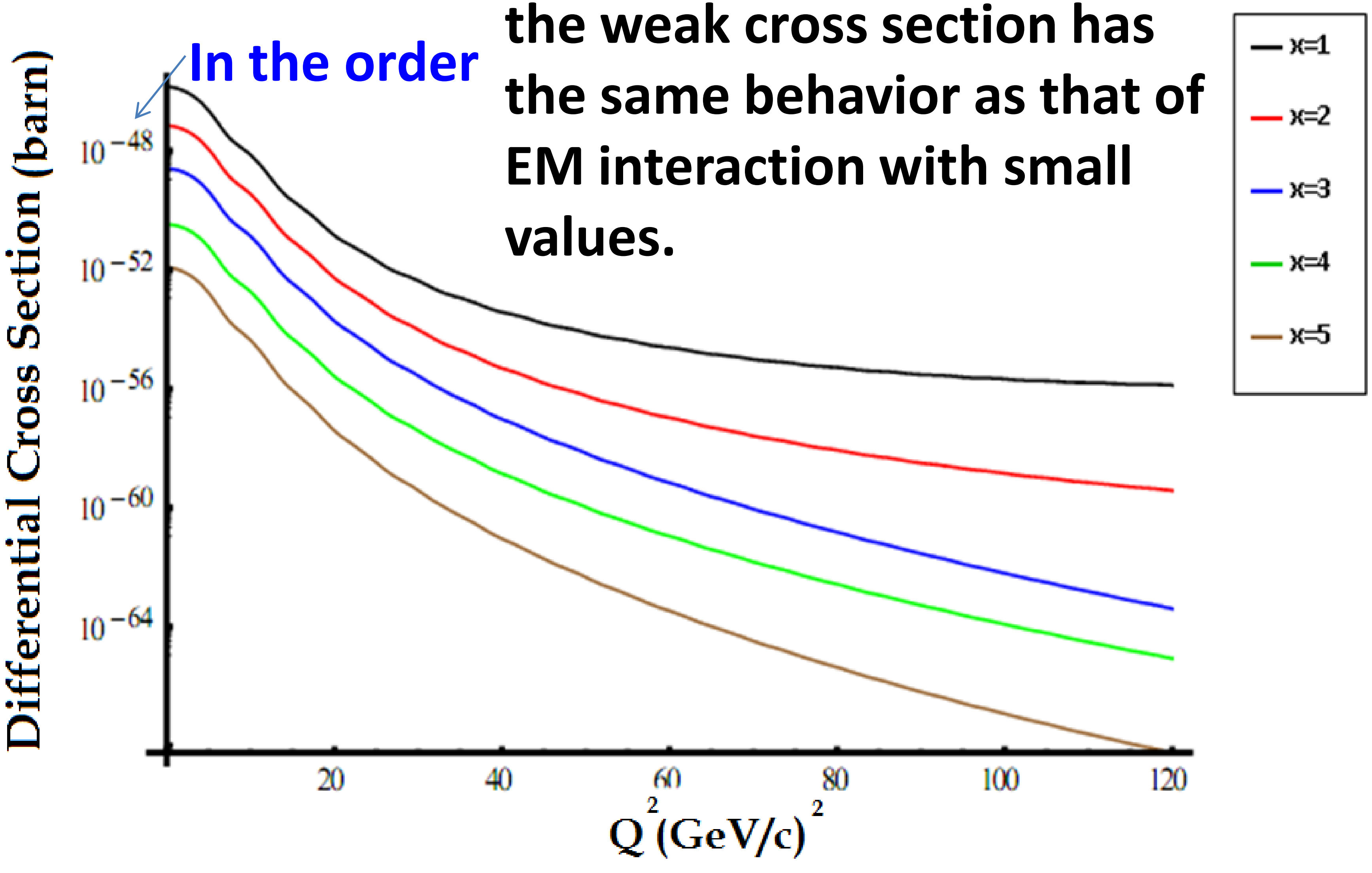
In the case of EM interactions at different values of x .

Cross section decrease with x



Results

the weak cross section has the same behavior as that of EM interaction with small values.



Any Question?

THANK YOU